

CHAPTER 8

DIESEL ENGINES

8-1. Diesel engine ratings

Diesel engines are the most common prime movers used for remote or emergency electric power generation. Those engines used for this purpose commonly range from 133 hp to 6,700 hp (100 kW to 5,000 kW), with rotational speeds ranging from 360 rpm for large prime power applications to as high as 1,800 rpm for small standby units. Thermal efficiency ranges from 30 to over 40 percent. For C4IRS Facilities applications, diesel engine prime movers shall be class A for continuous duty operation and shall be air-started and water-cooled. Spare engines available for service shall be kept in a ready-to-run condition by circulation of warm lubricating oil and warm jacket cooling water. This chapter will primarily address the requirements of diesel engines in the middle range of capacity and speed which are the most common. The engine manufacturer's directions regarding maintenance practices take precedence over any guidance provided in this chapter.

8-2. Types of diesel engines

Diesel engines are used as prime movers for many applications, but they are addressed here based on their use in electric power generation to drive generators.

a. Configuration. Diesel engines are available in two- or four-cycle configurations. Four-cycle engines are available in naturally aspirated or turbocharged models, but most engines are now purchased with turbocharging. Similarly, two-cycle engines are available with either a blower or turbocharger (some manufacturers use both in series), but turbochargers are supplied on most engines. Each type has its advantages in certain applications and has specific requirements for operation and maintenance due to the inherent differences. Two-cycle engines are frequently lighter weight for the same horsepower due to the fabrication of the engine block from steel plate instead of a casting and elimination of the valving common to four-cycle engines. In addition, they usually respond more quickly to rapidly changing loads, since they have less rotating mass than four-cycle engines.

b. Applications. Two major considerations in the level and amount of maintenance required for diesel engines are the application of the engine (emergency standby power or prime power) and the rotational speed of the engines. Emergency equipment which is expected to operate very few hours per year can be expected to last for years with minimal maintenance and utilize higher speed engines (i.e., 1,200 to 1,800 rpm). Prime power applications require significantly more maintenance and generally utilize lower speed engines (360 to 450 rpm) to maximize the useful life of components.

8-3. Diesel engine major system components

Diesel engines have many components and subsystems. Only those components which are typically mounted on the engine or engine skid will be addressed here. Descriptions of engine support systems, such as the fuel oil system, starting system, and lubrication system, are presented later in this manual.

a. Drivetrain. The drivetrain of the engine consists of the pistons, connecting rods, crankshaft, flywheel, coupling if any, and associated bearings.

b. Valve train and timing. This subsystem includes the gearing from the crankshaft to the camshaft, camshaft, tappets, push rods, rocker arms, valves, valve springs, and guides. In addition, the camshaft controls the fuel injection timing and actuates the injector in most contemporary engines with unit injectors. The description above applies to four-cycle engines; two-cycle engines move air into the cylinder and exhaust out through ports in the cylinder wall which are exposed by the movement of the piston. Some two-cycle engines have both ports and valves. Injection timing and actuation on two-cycle engines are still controlled by a camshaft.

c. Governor/control. The governor controls the speed of the engine. It is a sophisticated device which measures crankshaft speed and reacts to small deviations due to changes in load to maintain proper engine speed by adjusting the amount of fuel injected. Typically, two types of governors are used on diesel engines driving electric generators: self-contained mechanical-hydraulic type or remote electronic governor with separate engine-mounted actuator. Electronic governor systems with load sharing capability are the usual choice for multiple engine plants. Pulsating loads of some facilities have dictated the use of mechanical governors. Plants with multiple engines must have compatible governors to ensure proper operation of engines in parallel. Other control/safety alarm and shutdown indicators are summarized in table 8-1.

d. Turbocharger/blower. The turbocharger is a centrifugal compressor which is driven by the exhaust gases and in turn compresses the intake air to provide an increased mass of air to the combustion chamber. In-line engines typically have one turbocharger, and V type engines may have one or two turbochargers. Turbochargers are used on both two- and four-cycle engines, but many two-cycle engines utilize blowers to assist in scavenging air from the combustion chamber without significant increase in the density of the air.

e. Aftercooler. Turbocharged engines typically have an aftercooler downstream of the turbocharger to reduce the air temperature and increase the density of the air entering the combustion chamber. Cooling water is circulated through the aftercooler which is composed of finned tubes to cool the air to approximately 100°F.

8-4. Diesel engine system interfaces

Diesel engines interface with the following supporting systems.

a. Generators. Generators are the primary driven equipment for diesel engines. The diesel engine and the generator must be properly aligned and coupled, either directly or by a flexible coupling. It is critical that the engine and generator are properly matched and a torsional analysis of the engine/generator system has been performed by the engine manufacturer.

b. Fuel oil systems. The diesel engine is dependent on the fuel oil system to provide fuel to the injectors. The fuel oil must have the proper characteristics required for the specific engine installation. In general, larger slow-speed engines require a less volatile fuel than smaller high-speed engines. Special engine modifications are required where special fuels, such as Diesel Fuel Arctic (DFA) or heavy oil (No. 6) are used. Fuel oil systems are addressed in chapter 10.

c. Lube oil systems. The proper lubrication of the moving parts inside a diesel engine is critical to obtain satisfactory operation of the engine and maximum life of its components. The lube oil must be approved by the engine manufacturer and analyzed on a regular basis to determine the optimum interval for changing the lube oil and to monitor other indicators which indicate problems or a need for

maintenance. In addition, the analysis of the lube oil should include trace metal analysis for early indication of abnormal wear and scheduling maintenance or repairs. Lube oil systems cool and filter the lube oil to provide both proper lubrication and cooling of critical components within the engine. Refer to chapter 11 for further discussion of lube oil systems.

Table 8-1. Typical alarm and shutdown requirements for diesel engines

<i>Indication</i>	<i>Alarm Only</i>	<i>Alarm and Shutdown</i>
Engine System		
Overspeed		X
High Exhaust Temperature	X	
High Crankcase Pressure	X	
Low Injector Coolant Pressure	X	
High Inlet Manifold Temperature	X	
Lube System		
High Lube Oil Temperature	X	X
Low Lube Oil Pressure	X	X
Low Lube Oil Level	X	X
Fuel System		
High Fuel Oil Temperature	X	
Low Fuel Oil Pressure	X	X
High Fuel Filter Differential Pressure	X	
Generator System		
High Generator Bearing Temperature	X	X
High Generator Winding Temperature	X	X
Ancillary Systems		
High Coolant Temperature	X	
Low Coolant Level	X	
Low Jacket Water Pressure	X	
Low Starting Air Pressure	X	

d. Engine air system. The engine intake and exhaust systems provide filtered air to the engine and remove products of combustion from the engine room. These systems may incorporate such features as preheating or precooling of the intake air, or hardened design. Restrictions or blockage of either the intake or exhaust systems will severely impact engine performance.

e. Engine cooling system. Heat is transferred away from the engine by the cooling system and usually rejected to the air. The engine cooling system may consist of a single circuit which removes heat from the aftercooler and lube oil cooler, as well as the engine, or it may have separate circuits which allow lower temperatures to be maintained at the various components. The cooling system temperature is thermostatically maintained to ensure proper cooling and avoid thermal shock of high-temperature components. The heat is usually rejected directly through a radiator or indirectly via a heat exchanger to a cooling tower. The heat removed from the engine may be used to preheat combustion air in severe cold climates and also for heating the power plant building in prime power applications.

f. Engine starting air system. The vast majority of diesel engines installed in power plants are started with compressed air. Compressed air is directed by a distributor directly into the combustion chamber or is provided to an air motor which rotates the engine. Dedicated compressors typically provide starting air at 250 psig. The system must provide adequate storage to allow multiple attempts to start the engines. The compressed air start system will include two air compressor units, each with diesel engine-electric motor drive, and two main air storage tanks. The compressors will be rated at 250 psig operating pressure, and each will have a capacity capable of restoring any single storage receiver from 150 psig to 250 psig in 30 minutes or less. Each main storage tank will provide adequate air to the individual air start tanks at each diesel engine, supply air to the utility shop air outlets, and provide a second source of air to the instrument air system. Each air start tank will be sized to provide two 30-second start sequences without recharging and will be rated at 300 psig working pressure. Each main storage tank will have a volume equal to three air start tanks plus a volume equal to one instrument air receiver, and an additional volume to supply the utility shop air requirement.

g. Engine control systems. The basic control of the engine is maintained by the governor during operation, and the control is independent for each engine. The overall control of a multiple engine power plant can be relatively simple or very sophisticated. Possible control options range from local or manual starting and synchronization of each engine to automatic starting, synchronization, and load sharing of the engine generators. Engine control systems in advanced applications should also be integrated as a part of the SCADA (Supervisory Control and Data Acquisition) system.

h. Instrumentation. Collection of operating data is critical to planning maintenance and evaluating problems which may occur. In the past (and still the case at most facilities), all data were recorded by operating personnel from instrument panels at each engine. Many newer plants now have automated data logging systems which can also provide warnings for out-of-tolerance conditions and histories of unusual events which can improve the operation of the facility. Regardless of the type of system, data collection provides the basis for trend analysis which can indicate potential problems before they become severe.

i. Ventilation systems. Diesel engines operate at high temperatures and, therefore, reject large amounts of heat to the surrounding space. Diesel power plants are typically ventilated to remove this heat and to maintain temperatures within acceptable limits for both personnel and equipment. Proper operation of ventilation systems is required to avoid excessive temperatures, reduced equipment capacity, and potential equipment failures.

8-5. Operation of diesel engines

Consult the diesel engine manufacturer's manual provided with the engine for proper operating procedures and normal operating conditions. The operating procedures described below provide a general overview of diesel engine operation.

a. Prior to starting. Prior to starting, the engine prelube pump should be operated to ensure proper lubrication of the bearing surfaces. The prelube pump for a standby unit should be operated on a regular basis to maintain engine in "ready to start" condition. All engine auxiliary systems should be checked to verify proper status for engine operation. Failure to properly prelube the engine prior to starting can result in damage to engine components and significantly decrease engine life.

b. Starting. Normal starting of the engine should include the following items. The engine should be started without load and brought up to operating temperature before load is applied, verify lube oil pressure is normal immediately after starting, and be prepared to shut engine down if problems occur.

c. Normal operation. Under normal circumstances, do not operate the engine below 50 percent load or above 100 percent load for extended periods of time. Operation at low loads can cause carbon formation and rapid deterioration of the lube oil. Operation at high loads results in higher temperatures and pressures in the combustion chamber and can lead to more frequent maintenance or replacement of components. Operators should verify proper operating conditions exist on an hourly basis, and data should be recorded at least once per shift. Priority should be given to maintaining correct lube oil and coolant levels and checking the pressure difference across the inlet air filters, fuel filters, and lube oil filters.

d. Shutdown. Diesel engine should be unloaded and allowed to cool down prior to shutdown of the unit. The engine should be operated without load at rated speed until exhaust temperature decreases to recommended level and then at low idle speed, if applicable, for a minimum of five minutes without load or as directed by manufacturer.